BIORETENTION BASIN

General

Bioretention basins are infiltration devices used for the treatment and infiltration of stormwater runoff. A bioretention basin is made up of several layers, which treat stormwater as it is filtered. These basins remove pollutants and reduce runoff volume and temperature. Bioretention basins can be used as a stand-alone method of stormwater treatment or in conjunction with other stormwater management practices.

Bioretention basins are best suited to treating small drainage areas adjacent to runoff source areas, such as parking lots or streets. Appropriate placement of bioretention basins is important because of the need for proper maintenance. For example, basins located in open, visible areas are more likely to be properly maintained and, in turn, provide aesthetic value. Also, bioretention basins should not be used near foundations, basements, roads, or on sites with high water tables or steep slopes. Bioretention basins are susceptible to clogging with sediment and, therefore, should not be used for erosion control during construction.

Advantages

- Promotes infiltration of stormwater
- Reduces pollutants in runoff
- Decreases peak flow rates and volumes of runoff
- Helps preserve base flow in streams
- Reduces temperature impacts of runoff

Disadvantages

- Not suitable for construction site erosion control
- Susceptible to clogging
- Damaged by runoff with large amounts of salt-based deicers
- Not suitable for drainage areas larger than 2 acres

Design

For complete design of bioretention basins, please refer to DNR Standard 1004. Bioretention basins should be designed with careful consideration given to each of the following key components: drainage area and pretreatment, ponding zone, vegetation and mulch layer, engineered soil layer, storage layer, underdrain, and sand/native soil interface layer (refer to Figure 1).

Drainage Area and Pretreatment

The maximum drainage area allowed for a bioretention basin is 2 acres and the drainage area should not contribute significant sources of sediment. To maintain flow towards the basin, slopes should not be less than 0.5% for paved areas and 1% for vegetated areas. In any case, the slopes toward the basin should not be greater than 20%.

Although not required, pretreatment options should be explored. Pretreatment is intended to reduce the initial amount of pollutants in the runoff going to the basin. Several options for pretreatment are available, including settling basins, vegetated swales, and filter strips. Pretreatment should be chosen based upon site conditions and constraints.

Ponding Zone

The ponding zone receives and holds runoff until it has an opportunity to infiltrate. The ponding depth may not exceed 12 inches and the drawdown time must be a maximum of 24 hours. The side slopes of the ponding area should not be steeper than a 2:1 horizontal to vertical ratio.

Vegetation and Mulch Layer

The vegetation and mulch layer is the first layer to be infiltrated by the runoff. When establishing the vegetation layer, plants or plant plugs should be used rather than seed. When choosing what type of vegetation to use, native species that are able to handle the different environmental conditions of a basin should be selected. Turf grass or invasive plants shall not be used to vegetate the basin.

The mulch used shall be hardwood to prevent excessive floating and be free from any foreign material. The mulch should be spread in a uniform layer 2-3 inches thick.

Engineered Soil Layer

The engineered soil layer is composed of sand, compost and topsoil. The compost must meet the Wisconsin Department of Natural Resources Specification S100 for compost. The sand must meet the specifications found in the DNR technical standard 1004 and the topsoil must be classified as a sandy loam, loamy sand or loam texture soil according to the USDA classification system. The engineered soil layer must have a minimum depth of 36 inches. If gravel is used for the storage layer, a layer of pea gravel with a 4-inch maximum depth may be used between the engineered soil layer and the gravel storage layer. The pea gravel layer can be considered part of the 36-inch soil layer and prevents the engineered soil from settling down into the storage layer.

Storage Layer

The storage layer promotes infiltration. Since infiltration is the only way water is able to exit the storage layer, it is an important component of the bioretention facility. A storage layer is necessary when the native soil has an infiltration rate of less than 3.6 inches per hour. The maximum depth of the storage area is 48 inches. The storage layer may be composed of sand or clear washed stone of uniform size (i.e. 3 inch clear stone).

Underdrain

An underdrain pipe should be placed at the top of the storage layer as a stable outlet for runoff that cannot be infiltrated as quickly as needed. The pipe must be a minimum of 6 inches in diameter and made with materials that can withstand large loads. The perforations in the underdrain should allow the pipe to drain at full capacity, while maintaining the integrity of the pipe.

In order to prevent clogging in the underdrain pipe, the pipe must be protected with either filter fabric or a filter sock. If the storage layer is sand, filter socks must be used. When a filter sock is used, the openings in the sock must be small enough to keep out sand particles, but must not restrict the flow through the perforated pipe. Another acceptable option of pipe protection is a layer of pea gravel. If pea gravel is used, it must be a layer 4 inches thick to be adequate. The pea gravel must be washed and large enough that it will not fall through the perforations in the pipe.

The underdrain must have a clean-out port that can be accessed as needed for maintenance. The underdrain must discharge to a stable outlet, such as swales or storm sewers. If it is possible for backflow to occur, a check valve should be installed.

Sand/Native Soil Interface Layer

An interface layer is necessary when the infiltration rate of the native soil is less than 3.6 inches per hour. The interface layer shall be formed by a layer of sand three inches deep, which is vertically mixed with the native soil to a depth of 2 to 4 inches.

Other Considerations

To regulate the maximum ponding depth of the basin, overflow devices such as a weir or standpipe should be installed. The discharge from these overflow devices must be directed to a stable outlet.

If the basin does not include an underdrain, observation wells must be installed to monitor the basin function. Observation wells must be positioned in the center of the area to be monitored. The maximum area served by one well is 1,000 square feet.

Construction

- Runoff shall not be allowed in the basin until after the tributary area is stabilized
- Construction of the basin should only occur during suitable site conditions - if construction of the basin occurs during saturated soil conditions, the soil in the device could be unnecessarily compacted
- Compaction of the soils used for the bioretention device must be avoided - heavy equipment may not be used in the construction of the basin

- The engineered soil shall be premixed before placement and be dry enough to prevent clumping and compaction
- The engineered soil should be placed in several 12-inch deep lifts
- The basin should be mulched before the planting of the vegetation in order to prevent compaction

MAINTENANCE

- Accumulated sediment in pretreatment devices should be removed as needed
- Bioretention basins should be inspected semi-annually
- Additional mulch should be added at least once a year and as needed to maintain 2-3 inches of cover
- Bioretention basins should be inspected monthly for signs of erosion and sediment accumulation - all necessary repairs should be performed immediately

METHOD TO DETERMINE PRACTICE EFFICIENCY

A properly designed bioretention basin that has been sized to meet the applicable infiltration performance standard is assumed to have a sediment reduction efficiency of 80% and oil and grease removal that meets county treatment standards.

In order to determine the infiltration performance of this practice SLAMM, RECARGA or other approved models may be used. Additional information regarding acceptable modeling of infiltration in Manual.

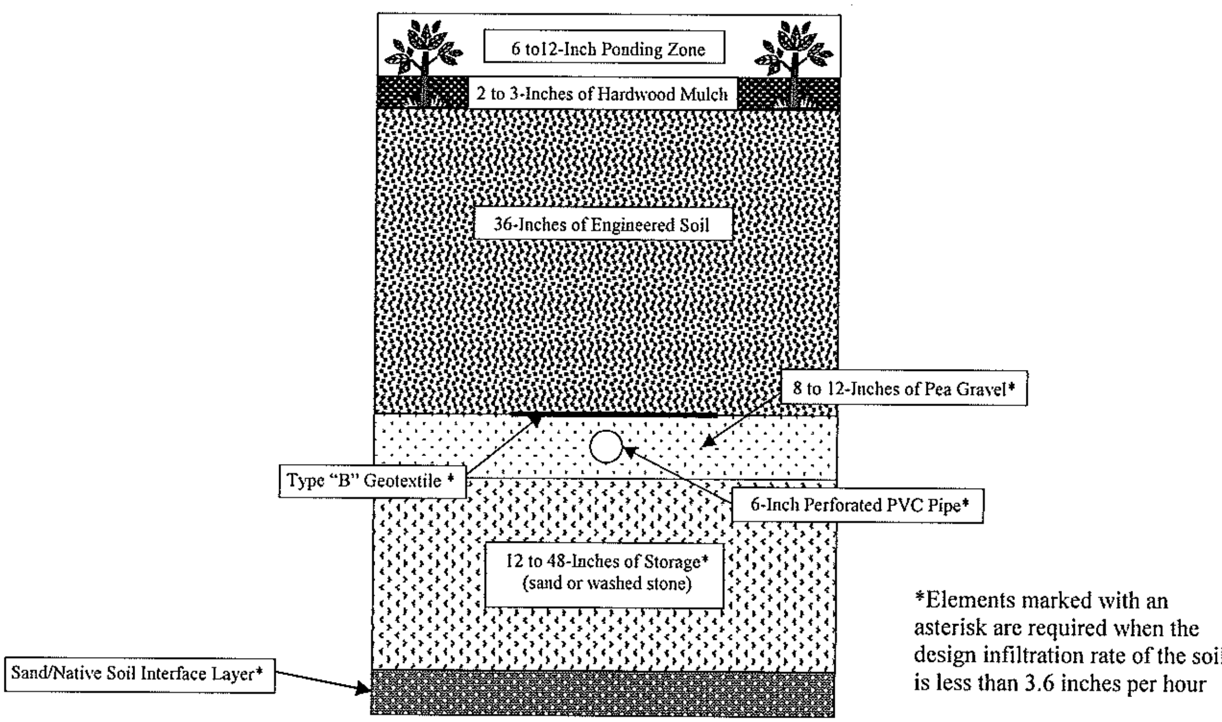


Figure 1. Bioretention Basin Layers

SOURCES

1. United State Environmental Protection Agency. Stormwater Technology Fact Sheet: Bioretention. Publ. EPA-832-F-99-012. Office of Water, Washington D.C., 1999.
2. Wisconsin Department of Natural Resources. For Sizing Infiltration Basins and Bioretention Devices to meet State of Wisconsin Stormwater Infiltration Performance Standards. DNR Technical Notes. Last Update: July 2006.

DEWATERING

General

Dewatering is a practice where sediment-laden water is pumped into a compartmented container, settling basin, filter, or other appropriate best management practice to trap and retain sediment. This practice detains sediment generated during the removal of water from a site prior to discharging it off-site and/or to waters of the state.

Dewatering applies where sediment-laden water must be removed for construction. The selection of a dewatering practice is dependent upon the predominant soil texture encountered at the dewatering site with consideration given to pumping rates, volumes and device effectiveness. Users of the practice of dewatering should be conscious of applicable federal state, and local laws, rules, regulations, or permit requirements governing the use and placement of dewatering.

Advantages

- Reduces the amount of sediment leaving the site
- Allows for a more in-depth site assessment – additional necessary erosion control measures may be identified

Disadvantages

- Must abide by multiple government laws and standards and obtain appropriate permits
- Requires frequent maintenance
- May be costly

Site Assessment

The proposed site must be assessed and documented to determine the site characteristics that will affect the placement, design, construction and maintenance of dewatering activities. Characteristics such as ground slopes, drainage patterns, runoff constituents, soil types, soil conditions, sinkholes, bedrock, proximity to regulated structures, natural resources, and specific land uses must be included in the site assessment. The documented site assessment should include the following:

- Soil textural class for dewatering areas with investigation extending below grading and trenching depths
- Storm sewer and sanitary locations
- Potential contaminates already in the soil, such as odor or discoloration other than sediment, or an oily sheen on the surface of the sediment-laden water – notify DNR Spills Reporting if present
- Seasonally highest water table depth
- Transport method and distance to receiving waters
- Discharge outfall locations

The Wisconsin Department of Natural Resources (WDNR) must be contacted when dewatering discharge will enter a WDNR listed *Exceptional Resource Water*, *Outstanding Resource Water*, or a wetland in an area of special natural interest. Additionally, if the discharge of the dewatering activity were to directly or indirectly enter a stream, the discharge flow rate must not exceed 50 percent of the peak flow rate of the 2-year, 24-hour storm event. General criteria applicable to dewatering activities are outlined in WDNR Conservation Practice Standard, Code No. 1061.

Soils

The selection of the dewatering practice depends upon the predominant soil texture encountered at the dewatering site. Refer to Figure 1, the USDA Soil textural triangle, to assist with classifying the soil of the site. Figure 2, Dewatering Practice Selection Matrix, illustrates acceptable dewatering options and their effective ranges. Pumping rates, volumes, and device effectiveness must also be considered when selecting a practice.

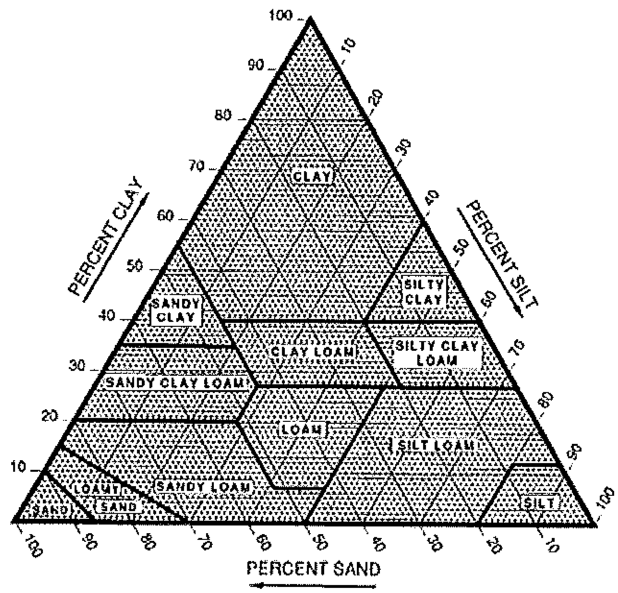


Figure 1: USDA Soil Textural Triangle
Source: WDNR

PRACTICES

Dewatering can be preformed in a variety of ways and should be selected based upon the individual site characteristics. The accepted dewatering practices are geotextile bags, gravity based settling systems, passive filtration systems, and pressurized filtration systems.

GEOTEXTILE BAGS

Geotextile bags are gravity-based filter bags not contained within any vessel or enclosure. Geotextile bags are widely used on sites where there is no available space for a sediment basin. The footprint of the bag, however, should be no smaller than 100 square feet. They lie on the ground and are designed to collect silt and sediment from pumped water. Sediment-laden water is pumped from the site and discharged into the bag that is securely attached to the discharge pipe. The almost sediment-free water discharges through the walls of the bag, while the sediment is retained inside the bag. Disturbing the bag may break up the cake of collected sediment and reduce its efficiency.

Geotextile bags should be sized according to the particle size being trapped, expected flow or pumping rate per square foot of fabric and a 50% clogging factor. Geotextile bags should meet the criteria listed in Table 1.

Polymers may be used to enhance the efficiency of the geotextile bags, but must meet the performance requirements of WDNR (refer to Polymer Application, pg. I.P-3).

Property	Test Method	Type I Value	Type II Value
Maximum Apparent Opening Sizes	ASTM D-4751	0.212 mm	0.212 mm
Grab Tensile Strength	ASTM D-4632	200 lbs.	300 lbs.
Mullen Burst	ASTM D-3786	350 psi	580 psi
Permeability	ASTM D-4491	0.28 cm/sec	0.2 cm/sec
Fabric	Nominal Representative Weight	8 oz	12 oz

Table 1: Properties for Geotextile Bags
Source: Adapted from WDNR

GRAVITY BASED SETTLING SYSTEMS

The settling of particles is the primary means of treatment for gravity based settling systems. Therefore, sufficient detention time is required when using this practice. Practices include portable sediment tanks, sediment traps, sediment basins and wet detention basins. WDNR approved polymers can also be used to enhance the settling.

Portable sediment tanks are intended to settle only sands, loamy sands, and sandy loams. If polymer is added, these tanks will additionally be appropriate for settling loams, silt loams and silts. Portable sediment tanks should be at least three feet deep and have a minimum of two baffled compartments. The inlet and outlet pipe should be a minimum diameter of three inches. To account for the settling of suspended sediments, one must determine the appropriate size of a tank. Multiply the pumping rate (gallon per minute) by 1.83 (a factor that includes the conversion from gpm to cfs and the particle settling velocity for Soil Class 1) to calculate the surface area of a tank in square feet.

Sediment traps and basins are temporary sediment control devices, while wet detention basins are generally permanent structures designed to address post-construction pollutant reduction requirements. The design, installation, and operation of sediment traps and basins should meet WDNR requirements

Passive Filtration Systems

Passive filtration systems also rely on filtration as the main means of removing sediment. The distribution of particle size in the stormwater influences sediment removal efficiency. Manufactured filters should be sequenced from the largest to the smallest pore opening. Available are sand media filters with automatic backwashing features that can filter to 50 μm particle size, screen or bag filters that can filter down to 5 μm, and fiber wound filters that can remove particles down 0.5 μm.

Other practices include filter tanks, filter basins, vegetative filters, grassed swales, and filtration fabric and should be installed, operated, and maintained according to manufacturer recommendations and WDNR.

Pressurized Filtration Systems

Designed to handle higher flow rates, pressurized filtration systems have the water flowing through the media pressurized, rather than depending solely on filtration. Pressurized filters are composed of individual filters that are most effective when larger particles have been removed by prior treatment with a weir tank, sand filter, etc. Practices include portable sand filters, wound cartridge units, membranes and micro-filtration units.

Pressurized filters have automatic backwash systems that are activated by a fixed pressure drop across the filter. Returning backwash water to the tank may be necessary if the volume of the backwash water is minor or substantially more turbid than the stormwater stored in the tank. Further means of treatment, such as land application, and disposal may be necessary to complete treatment.

Wound cartridge units are used when secondary filtration of sediments is necessary to remove fine particles such as clays. It is capable of removing sediment larger than 0.002 mm, but is most effective when used after larger particles have been removed by other treatment methods. Other practices include portable sand filters, membranes, micro-filtration, and polymers and should be installed and maintained according to manufacturer recommendations and WDNR (refer to Polymer Application, pg. I.P-3).

Maintenance

- Sediment must be frequently removed from devices and properly disposed of to maintain effectiveness
- Dewatering must be monitored and recorded on a daily log
- Install, operate, and maintain pressurized filtration systems by following manufacturer recommendations

Method to Determine Practice Efficiency

Dewatering practices reduce the amount of suspended sediment in water that must be removed from a site through filtering methods. The efficiencies for these practices vary by the type of device used and soil texture, pumping rates, volumes and device effectiveness. Devices that are constructed on site will have an efficiency that is determined by calculating the settling efficiency for the device.

Type of Dewatering Practice	Soil and Texture Classification			Notes
	Coarse Texture	Medium Texture	Fine to Very Fine Texture	
	Sandy, Loamy Sands, and Sandy Loams	Loams, Silt Loams, and Silts	Clay Loams, Silty Clays and Clay	
Geotextile Bags				
Type I	———	• • • •		
Type II	— — —	———	• • • •	
Gravity Based Settling				
Sediment Tank	———	• • • •		
Sediment Trap (Temporary)	———	• • • •		Use Standards 1063 or 1064
Sediment Basin (Temporary)	———	———	• • • •	Use Standard 1064
Wet Detention Basin (Permanent)	———	———	———	Use Standard 1001
Passive Filtration				
Filter Tank	———	———	• • • •	
Filter Basin	———	• • • •		
Vegetative Filter	———	———	———	Effectiveness depends upon the width of the filter and the runoff rate of flow. See Standard 1054 for design guidelines.
Pressurized Filtration				The contractor shall provide a certification sheet from the manufacturer specifying performance of the device based on the soil type and pumping rate.
Portable Sand Filter	———	• • • •	• • • •	
Wound Cartridge Units	— — —	———	———	
Membranes & Micro-filtration	— — —	— — —	— — —	Very effective but high maintenance requirements
Other Practices				
Sanitary Sewer Discharge	———	———	———	
Pump Truck	———	———	———	Transported to treatment facility
Alternative Method				Discuss alternate options with regulatory authority

Key:

Effective range of device: ———

Device applicable but may not be cost effective: — — — —

Effective range with addition of polymer: • • • • • • • • • • • •

Notes:

(1) The effectiveness of many practices can be enhanced through the use of polymer mixture

(2) Soils classification shall be done in accordance to an accepted method (i.e. USDA, AASHTO)

(3) Standard 1063 Sediment Trap

(4) Standard 1064 Sediment Basin

(5) Standard 1054 Vegetated Buffer for Construction Sites

(6) Standard 1001 Wet Detention Basin

(7) Discuss alternate options with the regulatory authority

Figure 2: Dewatering Practice Selection Matrix

Source: Adapted from WDNR

SOURCES

1. *Construction Site Erosion Control and Stormwater Management Procedures for Department Actions.* Wisconsin Administrative Code, Department of Transportation. November 2006.
2. *Dewatering.* Conservation Practice Standard. Wisconsin Department of Natural Resources. November 2006.
3. *Dewatering, Construction Practices for Environmental Stewardship.* AASHTO Center for Environmental Excellence. November 2006.
4. *Preliminary Data Summary of Urban Storm Water Best Management Practices.* United States Environmental Protection Agency. Washington, D.C. 1999.

EROSION MATTING

General

Erosion matting consists of a wide variety of organic or synthetic mats and blankets placed on the soil surface to reduce erosion from a site caused by concentrated runoff and raindrop impact. These devices are anchored to the exposed surface and help hold the soil in place by forcing runoff to pass through the matting, reducing its velocity and its ability to erode the exposed surface.

This practice is often used on sites where the gradient of the slope is such that mulching, by itself, is ineffective. It is implemented on slopes and in conveyance channels after final grading to prevent erosion and promote the establishment of permanent vegetation.

Advantages

- Effective practice for stabilizing soil
- Reduces flow velocity
- Encourages the establishment of vegetation and suppress weed growth
- May increase infiltration

Disadvantages

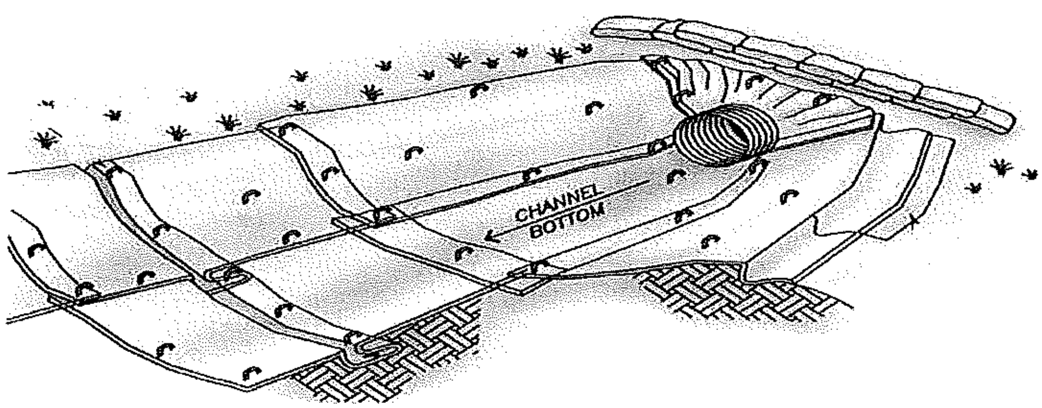
- Has a limited life span
- Reduced effectiveness with concentrated flows
- Not applicable on sites where the slope is steeper than 2:1

Types

Erosion mats and blankets are available commercially in many varieties of materials and life spans and, depending upon the type selected, may be used above or below grade. Traditional mats and blankets are biodegradable and may be composed of straw, wood, coconut fiber, or a combination and are held in place with netting on one or both sides of the mat. Turf-reinforcement mats (TRMs) are permanent devices, constructed from various types of synthetic materials, which are buried below the surface to help stabilize the soil. The life span of these devices will vary depending upon the type of netting and material used. As a result, careful selection is crucial to the practice's effectiveness. A current listing of approved erosion mats is available from the Product Acceptability List Committee on the Wisconsin Department of Transportation's web site at: http://www.dot.wisconsin.gov/business/engrserv/pal.htm.

Application and Installation

Erosion mats and blankets should be applied to the site beginning on the upslope edge, following all of

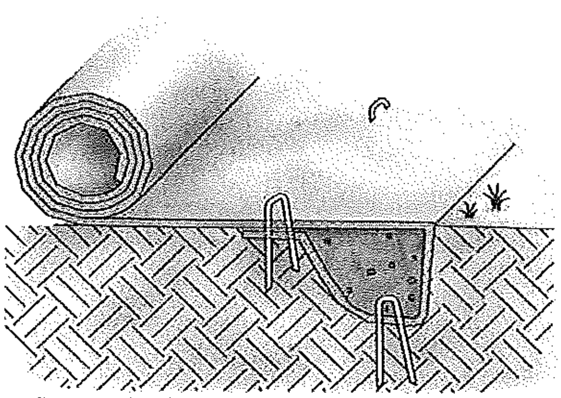


Proper Installation of Erosion Matting in a Channel
Source: Greenfix America

the manufacturer's specifications. The blanket should then be unrolled down the slope in a loose, uniform manner, without stretching the material and avoiding any wrinkles that may appear. This maximizes the effectiveness of the practice by promoting contact between the ground surface and the blanket, thus avoiding the possibility of concentrated flows from developing beneath the surface of the blanket.

Wherever possible, the material should be large enough so that one continuous sheet is applied over the entire channel or slope. Joints, where necessary, should be overlapped and stapled together. Vertical joints should be overlapped 2-4 inches and stapled at least once every 4 feet while horizontal, or end joints, should be overlapped 10 inches or more, with the upslope blanket overlaying the one down slope. Horizontal joints should be stapled together at least once every 12 inches to promote stability. In addition, mats and blankets must be anchored every 4 feet across the entire surface of the practice to ensure that they remain in place, however, they may not be used on sites with slopes steeper than 2:1.

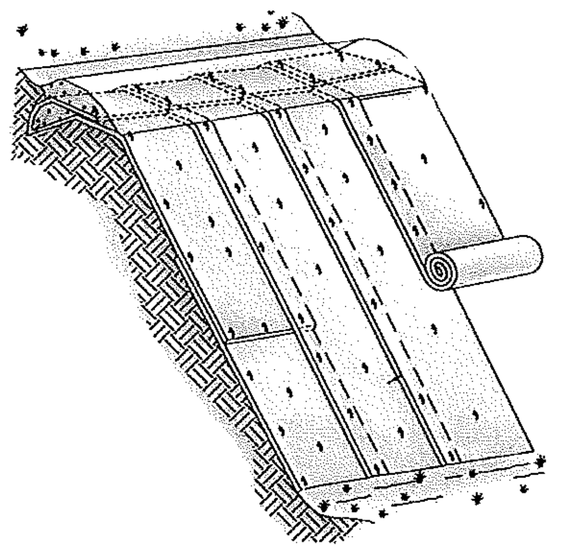
Erosion blankets should be anchored by either hardwood pegs or metal staples. The staples should be 11 gauge or higher and possess a 1-2 inch crown. Staple length, measured from top to bottom after bending, is dependant upon the soil conditions present on site. Staples and stakes must be at least 6-inches long for compacted soils, while loose, sandy soils require a length of 10 inches or more.



Proper Anchoring of Erosion Blankets
Source: Greenfix America

Construction and Maintenance

- Erosion mats and blankets should be installed immediately after the site has been graded and seeded
- Installation should follow the manufacturer's instructions to ensure the effectiveness of the practice
- Erosion mats should be inspected after each rainfall event for damage (evidence of undercutting or rill and gully formation) with all necessary repairs made immediately
- All other maintenance activities should follow the manufacturer's specifications



Proper Installation of Erosion Matting on Slopes
Source: Greenfix America

Method to Determine Practice Efficiency

The efficiency of erosion matting is dependant upon many factors, including site characteristics and the type of material used. However, in general, when properly applied and maintained, erosion matting provides the same efficiency as mulch (up to 88%; as derived by using a USLE C factor of 0.12) but may be used in areas of concentrated flow and on steeper slopes.

Sources

1. *Channel Erosion Mat.* Conservation Practice Standard. Wisconsin Department of Natural Resources. November 2006.
2. Greenfix America. Product Brochure. http://www.greenfix.com. 2006.
3. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council. Minneapolis. 2000.
4. Natural Resources Conservation Service. 1994. *Natural Resources Conservation Service Planning and Design Manual. Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater.* U.S. Department of Agriculture, Natural Resources Conservation Service and Mississippi Department of Environmental Quality. Washington, D.C. April 1994.
5. *Protecting Water Quality in Urban Areas, A Manual.* Minnesota Pollution Control Agency. St. Paul. 2000.

GRASSED SWALE

GENERAL

Grassed swales (or vegetated channels) are gently sloping, densely vegetated earthen channels that collect and transport stormwater and reduce the temperature of the water. These channels slow runoff and filter out suspended solids and pollutants while promoting infiltration, retaining runoff for a period of less than 24 hours. Stormwater enters the channel and is slowed by the dense vegetation that grows in the swale. As the runoff's velocity is lowered, sediments and pollutants are removed by the filtering action of vegetation.

Grassed swales may be used in conjunction with or as an alternative to curb and gutter systems, and may be used as a pretreatment device. They can be used on sites up to 50 acres in size, with the number and length of the swale depending upon the topography of the site and the size of the contributing watershed.

ADVANTAGES

- Relatively low cost
- Easily to construct and maintain
- Can be aesthetically pleasing if designed properly
- Very effective in preventing erosion
- Capable of carrying large quantities of stormwater

DISADVANTAGES

- Ineffective in flat areas and areas with very steep slopes
- Removes a small amount of pollutants
- Culverts reduce the effectiveness and feasibility of grassed swales
- Reduced effectiveness with large storm events
- Effective only as a pretreatment device on highly developed sites as it does not meet the 80% reduction in total suspended solids

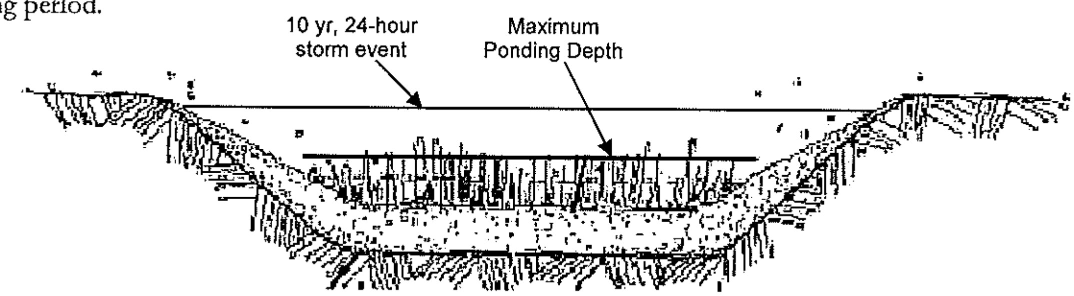
DESIGN

SOILS

Hydrologic soil groups A, B, and C are suitable with some restrictions, while coarse sands and gravel, by themselves, are generally not recommended because they provide little support for vegetation and have high infiltration rates, providing limited treatment ability. Soils with low permeability are also not recommended, as they do not allow the runoff to infiltrate during the short ponding period.

DIMENSIONS AND SLOPES

The length and width of swales will depend upon the individual characteristics of the site and must be capable of conveying the runoff from the 10 yr, 24-hour storm event and should also prevent erosion of the channel during this storm event. In general, however, swales should be between 2 and 8 feet wide. Widths greater than eight feet are not suggested, as channelized flow is likely to result.



Example of a Grassed Swale

Source: Modified from United States Natural Resources Conservation Service

Swales may provide a shallow ponding area for runoff, with a maximum depth of 18 inches.

The side slopes of the swale should have a horizontal to vertical ratio no greater than 3:1, and generally a ratio of 4:1 or flatter is recommended. These slopes increase the surface area of the channel, make maintenance tasks easier, and improve the safety of the device.

Longitudinal slopes are generally dependant upon the topography of the site, but they should prevent runoff velocities from exceeding 5.0 feet per second. In most cases, swales function best with a longitudinal slope of 1-3%. Slopes less than 1% may cause excessive ponding and sediment deposition, while slopes greater than 4% often result in high velocities. High velocities increase the potential for channel erosion, and may require that stone check dams or erosion matting is installed on such steep slopes (refer to Stone Check Dams, pg. I.S-8; and Erosion Matting, pg. I.E-1). Stone check dams are vertical drops of between 6 and 24 inches that help to reduce the slope of the channel and the velocity of the water. Their use is limited, however, as they often require additional energy dissipating structures and must be spaced at least 50-100 feet apart to prevent erosion of the channel.

Shape

Swales should be designed with a trapezoidal shape. V-shaped are not recommended as they may erode during high flows.

Vegetation

Plant selection will depend upon individual site characteristics such as the length of inundation in the swale and the amount of light available. Native species provide many benefits when compared to other species and are strongly encouraged. However, native species should be selected carefully (refer to Native Plants, pg. I.N-1). Care should also be taken to avoid the use of invasive and exotic species. Whatever the species that is selected, it should be tolerant to inundation, have the ability to form a dense sod, and resist matting. In roadside situations, vegetation should be tolerant of salt. In instances where time is not available for the proper establishment of seed, sodding or temporary seeding is generally preferred.

Vegetation should be maintained between 3 to 8 inches in height, and should extend above the ponding depth at all times. Fertilizer and pesticide use, if necessary, should be applied sparingly and only during dry periods of the year to prevent further runoff pollution.

Maintenance

- Swales should be inspected periodically during the first year of use and after all major storm events in perpetuity for possible erosion to the channel
- Trash and other debris should be removed seasonally
- Stone check dams should be inspected for evidence of bypassing
- Channelization, barren areas, and low spots within the channel should be repaired and reseeded
- Accumulated biomass should be removed periodically

Method to Determine Practice Efficiency

Grassed swales are designed as stormwater conveyance channels and provide little treatment ability. As a result, no efficiency is given for this practice.

Sources

1. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council. Minneapolis. 2000.
2. *New York State Storm Water Design Manual.* New York State Department of Environmental Conservation. New York. 2001.
3. *Stormwater Management.* Massachusetts Dept. of Environmental Protection. Volume Two: Stormwater technical Handbook. Boston. March 1997.
4. *Water Related Best Management Practices in the Landscape.* U.S. Department of Agriculture, Natural Resources Conservation Service and Center for Sustainable Design at Mississippi State University. Washington, D.C. 1999.

GABION

General

Gabions are rock-filled, multi-celled, PVC coated wire baskets that are placed in ponds (as an outlet structure), swales, and vegetated channels to dissipate the water's energy. Gabions absorb a great deal of the water's energy by forcing water to pass through the voids in the structure, which reduces its velocity, promoting sedimentation and reducing channel erosion.

Gabions may be used in swales and vegetated channels that outlet to sediment traps and basins. They are very versatile structures that may conform to a wide variety of situations and sites and may be constructed on site or purchased commercially. As a result, materials should be selected carefully to ensure proper function and stability.

Design

The size of the structure will depend upon the site, but should have a height of at least 1 foot; have a minimum bottom width of 3 feet; and should extend across the entire conveyance structure with slopes no steeper than 2:1. In addition, gabions must be underlain with geotextile filter fabric to protect the structure from undercutting, which may cause the failure of the device.

The stone selected for use in gabions will vary depending upon the individual needs of the site, but should be 1 to 8 inches in diameter and be clear of fines and other sediment. Gabions may be filled by mechanical methods, but it is generally recommended that they be filled by hand. Hand filling ensures that the entire volume of the gabion is occupied, increasing the strength and durability of the practice.

Baskets are constructed of PVC coated wire mesh that is resistant to corrosion. After they have been filled, the gate should be closed tightly and securely wired shut.

Advantages

- Relatively inexpensive
- Requires little maintenance
- Easy to construct
- Can be aesthetically pleasing if designed properly, which may increase adjacent property values
- Supports plant life
- Excellent for retrofit applications

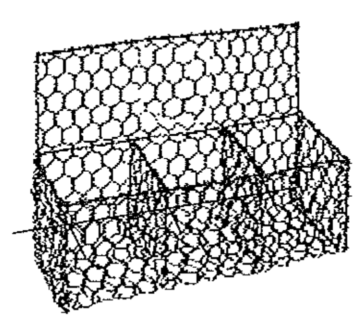
Disadvantages

- Adjoining materials may require additional stabilization to prevent erosion

should be securely wired to existing gabions.

Construction

- To maintain its shape, the basket shall be braced with wire supports in both directions
- Gabions are anchored into the walls of the channel laterally and to the ground vertically by weight - buried portions must be wrapped with 12 ounce, non-woven filter fabric
- To prevent the erosion of downstream materials, stone should be placed at the toe of the structure
- Gabions should be underlain by geotextile filter fabric
- Gabions should be constructed immediately after grading is completed on the conveyance structure



An Example of a Gabion

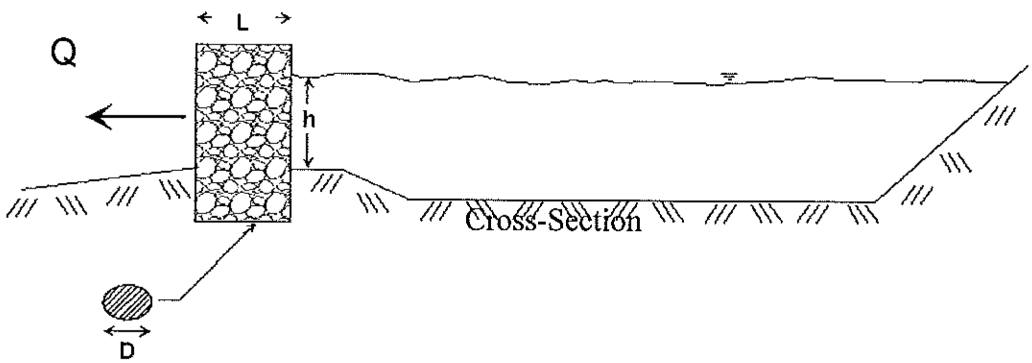
MAINTENANCE

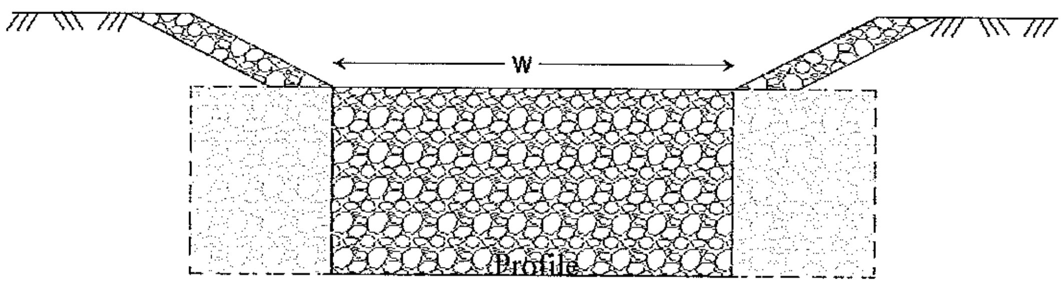
- Gabions should be inspected periodically and after all storm events for evidence of undercutting and the erosion of adjacent materials
- Gabions may require additional stone to offset settlement and loss

METHOD TO DETERMINE PRACTICE EFFICIENCY

Gabions reduce the amount of suspended sediment in stormwater by reducing the flow velocity of water. The efficiency for this practice is determined by calculating the settling efficiency for the device from the equation below.

CALCULATING FLOW THROUGH A GABION





$$Q = \frac{h^{3/2} W}{\left[L/D + 2.5 + L^2 \right]^{1/2}}$$

Q = Total flow through dam (cfs)
h = Ponding depth in basin (ft)
W = Total length of dam(ft)
L = Horizontal flow path length (ft)
D = Average rock diameter (ft)

A Typical Gabion Structure

SOURCES

1. *Georgia Stormwater Management Manual. Volume 2: Technical Handbook.* Atlanta Regional Commission. Atlanta, Ga. 2001.
2. *National Catalog of Erosion and Sediment Control and Stormwater Management. Guidelines for Community Assistance.* U.S. Department of Agriculture, Natural Resources Conservation Service. Washington D.C. 1996.
3. *Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater.* U.S. Department of Agriculture, Natural Resources Conservation Service and Mississippi Department of Environmental Quality. Washington, D.C. April 1994.

INFILTRATION BASIN

General

Infiltration basins are depressions that collect and store stormwater until it can infiltrate into the subsoil. Sediment settles out in the device, and nutrients, metals, and organic material are adsorbed by the soil as the water infiltrates. Infiltration basins may also be designed to reduce peak flows from a site if the storage capacity of the device is increased and a stable outlet structure is included in the design.

Infiltration basins are appropriate on sites with highly permeable soils and drainage areas of less than 15 acres. Infiltration basins should not be used near foundations, basements, or roads or on sites with high water tables, steep slopes, or clay soils. In addition, these devices must not be used on sites with large concentrations of soluble pollutants, as groundwater contamination may result.

While these structures effectively treat the runoff volume from small storms, larger storm events quickly overwhelm the capacity of the device and render it ineffective. Basins are also susceptible to clogging from sediments and, as a result, they must be used in conjunction with other management practices, such as pretreatment for sediment removal.

Advantages

- Increases discharge to the groundwater
- Preserves base flow in streams
- Removes sediment, nutrients, and organic material from stormwater
- May be designed to reduce peak flows
- Reduces thermal impacts of runoff

Disadvantages

- Limited functionality with frozen ground
- May cause ground water pollution if not sited properly
- Susceptible to clogging
- Requires frequent maintenance
- Not applicable on sites with high sediment loads or sites with large concentrations of hydrocarbons

Design

Infiltration basins are depressions that collect and temporarily store runoff and should be designed to drain within 48 hours. To prevent erosion of the basin and to increase the infiltration capacity of the practice, they should be lined with vegetation that is tolerant to frequent inundation (refer to Seeding, Permanent, pg. I.S-3.1; or Native Plants, pg. I.N-1.1). The effective infiltration area must receive runoff that has been pretreated.

Stormwater must be delivered to the basin from pretreatment devices at non-erosive velocities to prevent erosion of the structure. The pretreatment device must provide TSS reduction of 80% for a 1-year, 24-hour storm event. Pretreatment for oil and grease separation may be necessary depending on tributary source areas. Basins receiving runoff from rooftops only do not require pretreatment.

The depth of the basin is dependant upon the infiltration rate of the soil and the retention time of the structure, and should have a length to width ratio of 3:1. The bottom of the basin must be at least 3 feet above the seasonally high water table to prevent groundwater contamination. Side slopes must be 3:1 or flatter to promote uniform infiltration and safety while making maintenance tasks, such as mowing, easier. A drawdown device must be included to provide winter pass through, and allow for timely maintenance.

In order to prevent channelized flow and extended localized ponding, large basins should be divided into multiple cells. Level spreaders that distribute the runoff over the effective infiltration area of each cell should be utilized. A drawdown device must be included for each cell in the basin.

An emergency spillway should be incorporated into the design of the structure to safely pass flows that exceed the design capacity of the basin. These structures prevent large flows from overwhelming the capacity of the structure without causing damage to the basin or downstream structures by discharging to stable outlets (refer to Stone Outlet Protection, pg. I.S-10.1; or Lined Waterway or Outlet, pg. I.L-1.1).

CONSTRUCTION

- Construction of the basin should not commence until the entire site has been stabilized to prevent sediment clogging
- Care should be taken during all phases of construction to prevent the compaction of soils in and around the practice
- Stabilize infiltration basins immediately after construction is completed

MAINTENANCE

- Accumulated sediment in pretreatment devices must be removed as needed
- Infiltration basins need to be inspected for signs of erosion and bare spots after all storm events until vegetation has become well established - all necessary repairs shall be performed immediately

METHOD TO DETERMINE PRACTICE EFFICIENCY

If the basin includes a forebay that is used for sedimentation, the sediment removal efficiency calculations in Appendix IV: Basin Efficiency may be used to calculate the level of pretreatment.

In order to determine the infiltration performance of this practice SLAMM, RECARGA or other approved models may be used. Additional information regarding acceptable modeling of infiltration practices is found in Appendix II.

SOURCES

1. *Georgia Stormwater Management Manual. Volume 2: Technical Handbook.* Atlanta Regional Commission. Atlanta, Ga. 2001.
2. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council. Minneapolis. 2000.
3. *Protecting Water Quality in Urban Areas, A Manual.* Minnesota Pollution Control Agency. St. Paul. 2000.
4. Wisconsin Department of Natural Resources. For Sizing Infiltration Basins and Bioretention Devices to meet State of Wisconsin Stormwater Infiltration Performance Standards. Last Update: July 2006. http://dnr.wi.gov/org/water/wm/nps/stormwater/technote.htm.

LINED WATERWAY OR OUTLET

General

Lined waterways or outlets are channels lined with stone and provide for non-erosive conveyance of runoff or concentrated flow in areas where grassed waterways or unlined channels are inadequate or not permissible.

These practices are applicable on sites where vegetation cannot be established due to shading; where a lining is required to control erosion; where high velocities, steep grades, seepage, prolonged base flow, or wetness would cause erosion; or where use by people or animals precludes the use of vegetated channels. Lined waterways or outlets are designed as conveyance channels and do not enhance water quality or reduce peak flows. As a result, they are best used in conjunction with other management practices.

Advantages

- Cost-effective
- Relatively easy to construct
- Prevents erosion to receiving structures

Disadvantages

- Large storm events may displace rock
- Removal of accumulated sediments is difficult
- Not applicable on steep slopes

Design

Lined waterways or outlets should be designed to convey the maximum designed outflow from the structure or structures that it serves. The maximum flow velocities for stone linings are determined from the median diameter of the stone (D_{50}) placed in the channel. However, on slopes steeper than 10%, a slope adjustment factor must be used.

The channel should be designed with cross sections that are triangular, parabolic, or trapezoidal. Side slopes should be 2:1 or flatter with a minimum freeboard of 0.25 feet above the designed flow depth.

Stone

Lined waterways or outlets should consist of clean, angular stone that is resistant to weathering. The stone should be sized by using the median stone size (D_{50}). Once the D_{50} has been selected, 50% of the stone, by weight, should be larger than the D_{50}.

However, the diameter of the largest stone should not exceed 1.5 times the D_{50} size. The remaining portion of the stone should be well graded with a sufficient amount of smaller stones to fill the voids between the larger stones.

The depth of the stone should be equal to the maximum stone size plus the thickness of any bedding or filter material. However, under no circumstances should the stone placed in the channel reduce the designed cross section of the channel.

Maximum Velocities for Various D_{50} Sizes and Shapes

Maximum Velocity (ft/sec)	D_{50} Cubical (inches)	D_{50} Spherical (inches)
10.8	12	14
9.9	10	12
8.8	8	10
7.6	6	8
6.3	4	6
5.0	2	4

Slope Adjustment Factors for Allowable Velocity

Slope (horizontal to vertical)	Slope ft/ft	Adjustment factor
3:1	0.33	0.80
4:1	0.25	0.85
5:1	0.20	0.89
6:1	0.17	0.91
7:1	0.14	0.92
8:1	0.13	0.93
9:1	0.11	0.94
10:1	0.10	1.00
12:1	0.08	1.00
15:1	0.07	1.00

Source: Natural Resources Conservation Service

Manning's "n" Values for Various Rock Sizes

Diameter (inches)	"n"
2	0.030
4	0.033
6	0.036
8	0.037
10	0.039
12	0.040

CONSTRUCTION

- Construction should be completed before any water is allowed through the outlet
- In applications where damage is possible to the outlet structure, the stone should be hand placed

MAINTENANCE

- Lined waterways and outlets should be inspected after all storm events for displaced stones – all necessary repairs should be made immediately
- Accumulated sediments should be removed periodically

METHOD TO DETERMINE PRACTICE EFFICIENCY

Lined waterways and outlets are designed as stormwater conveyance channels and provide little treatment ability. As a result, no efficiency is given for this practice.

SOURCE

1. *Wisconsin Field Office Technical Guide.* U.S. Department of Agriculture, Natural Resources Conservation Service. Washington D.C. 1993.

MULCHING

General

Mulching is the application of material to the soil surface to protect it from raindrop impact and overland flow. Mulch covers the soil and absorbs the erosive impact of rainfall and reduces the flow velocity of runoff, significantly reducing soil loss from a site.

Mulch may be applied after the site has been rough graded to control erosion. It provides a temporary cover that reduces soil loss and allows vehicular and foot traffic over the area. Mulch also provides benefits to the site beyond erosion control. Mulch forms a blanket over the soil, and moderates its temperature, conserving moisture and providing an environment conducive to seed germination. Mulch should be applied within 48 hours of the completion of seeding, or in hydroseeding applications, simultaneously (refer to Seeding, Permanent, pg. I.S-3 and Seeding, Temporary, pg. I.S-4).

Mulching is a versatile practice that is applicable on sites where sheet flow is maintained and slopes do not exceed 3:1. Mulch has a limited life span, which varies with the material used and site conditions. It may not be used in channels or other areas where concentrated flow may occur. In these situations, erosion blankets or mats, which are more effective and may have a longer life span, should be used (refer to Erosion Matting, pg. I.E-1). Mulching, while effective for smaller storm events, may not prevent erosion during larger storm events and is best used in conjunction with other management practices.

Advantages

- Cost-effective
- Easy to apply
- Protects the soil surface from raindrop impact, preventing erosion
- Reduces evaporation from the soil and moderates soil temperature
- Aids seed germination and establishment and hinders weed growth

Disadvantages

- Ineffective on slopes steeper than 3:1
- Ineffective with large storm events
- May require frequent maintenance

Types

Mulch is available in a variety of types and should be selected based upon the individual site characteristics, such as slope, soil type, size, and time of year the mulch is applied. Regardless of the material selected, it must be free of weed and grass seeds that may compete with the establishing seed.

Straw

Straw is the most commonly used mulching material as it is cost effective and easy to apply. Straw from small grains, such as winter wheat, oats, and rye are generally used and can be spread by hand or with mulching equipment. Because straw is susceptible to the wind, it must be anchored to the soil by an approved method.

Wood Chips, Bark, and Wood Fibers

Wood chips are often used as landscape mulches and in specialized applications. They are generally more expensive, but do not require anchoring and may be obtained from a variety of sources. The wood used for mulch may be a hard or soft wood and shall be free of mold, sawdust, and other foreign materials, such as bonding agents and other chemicals.

Like all other organic mulches, wood chips are biodegradable. However, as wood chips degrade, they typically absorb a significant portion of the available soil nitrogen, making it unavailable for the establishing seed. Thus, depending upon the nitrogen content of the soils present on site, nitrogen fertilizer may need to be applied along with wood products to encourage the establishment of seed. Tree bark, often obtained as a byproduct of the timber industry, is also used in landscape plantings and in areas that will not be closely mowed. Bark differs from wood chips in that it degrades faster and thus does not require added nitrogen.

Wood fibers consist of hard or soft wood that has been shredded in a hammermill, tub grinder, or other mechanical means. While wood fiber may not be used as a mulching material by itself, it is often used in conjunction with straw mulch in hydroseeding applications on steeper slopes and in critical areas.

Application

Rate

Mulch should be applied so that the soil surface is uniformly covered. This coverage rate corresponds with the application standards included in the following table. However, actual application rates may vary depending upon the individual site characteristics and the type of mulch used. The following table is intended for use as a planning tool only.

Application Rates by Material

Material	Rate Per Acre	Notes
Straw	1-2 tons	From small grains, should be tacked down or crimped
Wood Chips	5-6 tons	Treat with 12 lbs. of Nitrogen per acre; not to be used for fine turf
Wood Fiber	0.1-1 ton	May be hydroseeded, not for use in hot weather
Bark	35 cubic yards	Should be applied with a mulch blower or by hand. Not to be used with asphalt tackifiers.

Source: Adapted from NRCS Planning and Design Manual

Mulch may be applied by hand or by mechanical methods. Mechanical methods are generally much faster and more cost-effective, but may not distribute the mulch as evenly as hand application.
For hand application, the area to be mulched should be divided into sections with an area of 1000 square feet. Each section should then be evenly covered with 70-90 pounds of straw (roughly equivalent to 1½ - 2 bales). This method results in an application of 1½ to 2 tons per acre with a uniform thickness of 5-7 pieces.

Anchoring

Certain types of mulches, such as straw and wood fibers, are easily displaced by the wind and water. To keep them in place and effective, mechanical or chemical anchoring methods are applied. Mechanical means of anchoring include crimping and the use of erosion netting. Crimping is accomplished by a tractor drawn implement, similar to a farm disc, which draws the mulch into the soil profile in one piece. Crimping shall be performed on the contour of the land to prevent the formation of rills or gullies that may result from other application methods. Erosion nets, which are constructed of various materials such as plastic, wire, jute, cotton, or paper, are anchored on top of the mulch to hold it in place. Erosion nets are available in many types with a wide range of life spans. As a result, careful selection and adherence to all manufacturers' specifications are crucial to their success.

Chemicals, called tackifiers, may also be used to hold mulch in place. Tackifiers hold the fibers together and reduce their susceptibility to wind and water erosion. Many types of tackifiers are available, including latex based products, asphalt emulsifiers, and natural products, such as guar gum. The type of product used will depend upon the characteristics of the site and the type of mulch used, however, regardless of the material selected, application should follow all of the manufacturers' specifications.

Construction

- All grading activities shall be completed and the area seeded before mulch is applied (except in hydroseeding applications)
- Tackifiers shall not be applied in windy conditions
- Mulch, when applied correctly, will have a uniform thickness of 5-7 pieces

Maintenance

Mulch shall be inspected weekly and after each storm event (including windy days) for signs of displacement and rill erosion. Necessary repairs and/or replacement shall be performed immediately to preserve effectiveness. Inspections shall continue until vegetation has been permanently established.

Method to Determine Practice Efficiency

Mulching efficiency is dependant upon many factors, including site characteristics, type of mulch used, rate of application, and atmospheric conditions. However, in general, when properly applied, mulching provides an efficiency of up to 88% (derived by using a USLE C factor of 0.12).

Sources

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2. *Indiana Handbook for Erosion Control in Developing Areas.* Indiana Department of Natural Resources, Division of Soil Conservation. Indianapolis. 1994.
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6. *National Catalog of Erosion and Sediment Control and Stormwater Management. Guidelines for Community Assistance.* U.S. Department of Agriculture, Natural Resources Conservation Service. Washington D.C. 1996.
7. *Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater.* U.S. Department of Agriculture, Natural Resources Conservation Service and Mississippi Department of Environmental Quality. Washington, D.C. April 1994.
8. *Wisconsin Field Office Technical Guide.* U.S. Department of Agriculture, Natural Resources Conservation Service. Washington D.C. 1993.

PERVIOUS PAVEMENT

General

A pervious pavement system is a system that allows stormwater to percolate through small pores or gaps in the pavement. The purpose of these systems is to encourage infiltration by reducing the amount of runoff that is produced from a site. Runoff soaks through the voids in the pavement and into a basin that is filled with gravel, a layer of filter fabric, and a stone reservoir. These layers work together to both support the pavement above it and to speed percolation into the subsoil.

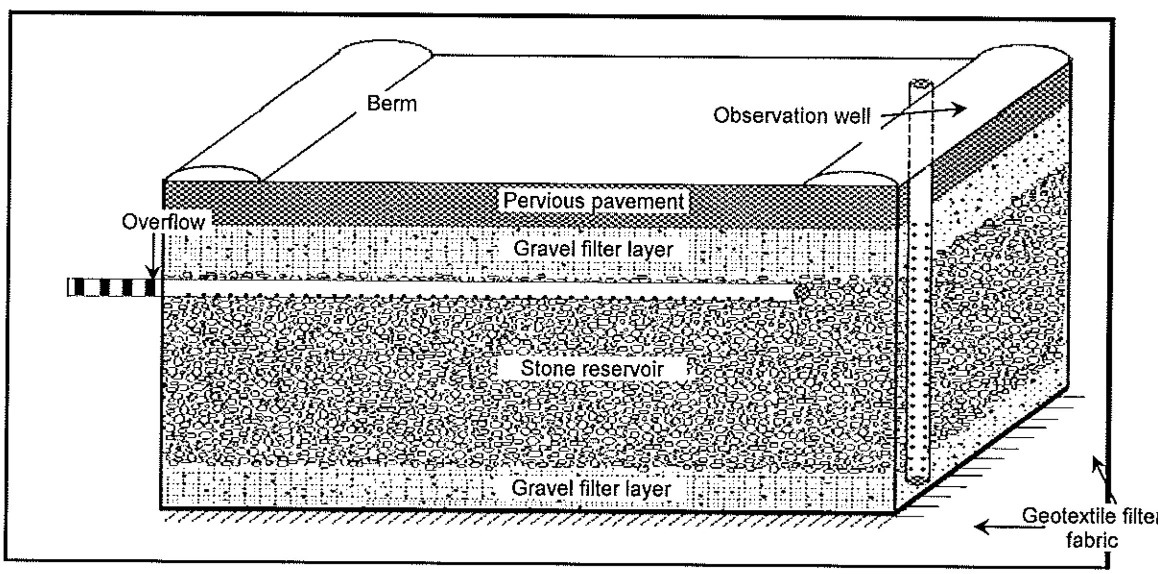
There are several types of pervious pavement systems. They include: porous asphalt, porous concrete, modular perforated concrete block, and cobble pavers with porous joints. These systems can be used in any area with limited traffic flow, such as overflow parking lots and driveways. Heavy traffic causes the soil beneath the pavement to become compacted and obstructs the downward flow of the water, limiting the system's effectiveness. These systems should be used in conjunction with other management practices to reduce the amount of sediment that reaches the pavement, as heavy loads of sediment can permanently clog the pores in the pavement, severely hindering the ability of the pavement to accept runoff.

Advantages

- Reduces the need for additional BMPs by reducing runoff
- Reduces temperature of runoff when compared to traditional pavement systems
- Can be aesthetically pleasing

Disadvantages

- Limits handicapped accessibility
- Ineffective in areas with high volumes of traffic
- May be damaged by snow removal activities
- Pores are easily clogged by sediment
- May increase the potential for groundwater contamination



An Example of Pervious Pavement
Source: Adapted from the United States Environmental Protection Agency

Design

Soils

Proper soils are necessary for pervious pavement systems to work correctly. The soil present on the site should have a permeability rate of at least 2 inches per hour and should be at least 4 feet thick to ensure that the pavement and the basin drain properly.

Storage Basin

Pervious pavement is underlined by a storage basin that aids in the drainage of water from the pavement to the subsoil. The basin consists of a layer of woven geotextile filter, 2 layers of gravel, a stone reservoir, an overflow pipe, and an observation well.

A geotextile filter with a high flow rate is placed on the bottom and along the sides of the basin. It is used because finer sediments, such as those contained in the subsoil, have a tendency to shift upward into the voids in the gravel and stone, reducing the infiltration capacity of the basin. The geotextile filter prevents this process from occurring, yet allows water to move freely through it.

2 layers of ½ inch gravel are placed in the basin: the first is located on top of the geotextile filter and the other directly beneath the pavement and above the stone reservoir. Both layers serve as a base for the layer above it; the top layer supports the pavement while the lower layer supports the reservoir above it and prevents settling under normal conditions.

A layer of 1 ½ to 3-inch stone is located between the gravel layers. It acts as a reservoir for the runoff, cooling it as it slowly passes through the stone. A perforated overflow pipe is located at or near the top of the stone and helps prevent runoff from leaving the site during large storm events. When large amounts of runoff infiltrate the basin, the reservoir may not be large enough to handle all of the runoff produced. The overflow pipe, which has holes in the bottom of it, drains water from the top of the basin when the basin is filled, but allows water to percolate downward when it is not.

To ensure the basin is working properly, an observation well is incorporated into the basin. Stretching the entire depth of the basin, it allows site owners to check the water levels in the basin and ensure that the runoff is infiltrating into the subsoil. As an added safeguard, the basin should be larger than the pervious pavement that is placed on top of it. If the voids in the pavement become clogged, the added surface area provides an overflow for any runoff that occurs. After paving, the remaining, exposed basin is covered with a decorative stone.

Placement

Pervious pavement systems should be placed in areas with limited traffic use and away from areas that see even occasional use by heavy machinery. Heavy machinery and large volumes of traffic cause the soil beneath the pavement to become compacted, causing the infiltration capacity of the soil to be reduced.

Construction

Pervious pavement failures occur most often during construction due to sedimentation that fills in the voids in the pavement. As a result, careful construction practices that significantly reduce the site's contact with sediment from construction vehicles and from around the site are essential to the success of these systems. Successful construction requires the use of stone tracking pads (refer to Stone Tracking Pads, pg. I.S-11) to reduce the sediment brought on site by vehicles and any practice that reduces the amount of sediment that runs off onto the site; such as buffers, filter strips, berms, or diversions. In addition, constant contact should be maintained between the contractor and the engineer to ensure that all aspects of the system are installed properly. The combination of these factors greatly increases the likelihood of a successful pervious pavement system.

Maintenance

Proper maintenance of pervious pavement is crucial to its operation, but is similar to that required with traditional pavement. The main difference is that pervious pavement should be vacuumed by using a Hi-Vac truck or other device rather than swept. Sweeping may actually expedite sedimentation by brushing sediments into the pavements voids, blocking the percolation of runoff. Vacuuming removes sediment and debris without spreading it around and is more efficient at removing sediment than traditional street sweeping equipment. Vacuuming should be performed at least 2-3 times a year to ensure that water is infiltrating properly. In addition, signs should be placed at various locations throughout the site after construction is completed stating that pervious pavement is located on the site. The signs should warn heavy machinery and snow plow operators to avoid the area.

Method to Determine Practice Efficiency

Pervious pavement systems are designed as an infiltration practice and do not significantly reduce the amount of suspended sediment in stormwater runoff. As a result, no efficiency is given for this practice.

Sources

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2. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council. Minneapolis. 2000.
3. *Preliminary Data Summary of Urban Storm Water Best Management Practices* (EPA-821-R-99-012). U.S. Environmental Protection Agency. Washington, D.C. August 1999.

POLYMER APPLICATION

General

Polymers (PAM), or anionic polyacrylamides, are non-toxic, organic chemicals that can be applied to soil or water and will temporarily bond soil aggregates. The resulting soil surface is significantly more resistant to erosion than untreated soil. Water application of polymers promotes sediment flocculation and coagulation, thereby increasing settling velocity.

PAM is applicable on a wide variety of sites, especially those with steep slopes where traditional practices, such as mulching, are rendered ineffective when used by themselves. PAM may also be used to improve the efficiency of devices that rely on settling of particles in water. This practice is usually used during and after site grading activities, prior to and during the establishment of seed, (refer to Seeding, Permanent, pg. I.S-3; and Seeding, Temporary, pg. I.S-4) or in situations where other practices are unavailable or ineffective due to weather conditions. The use of additional practices, such as mulching, (refer to Mulching, pg. I.M-2) may significantly increase the effectiveness of the practice.

For water application, polymers may only be applied to runoff that has been captured in sediment control devices. Application of polymers in these devices helps sediment suspended in the water to settle out. Polymers may not be applied directly to any surface waters of the state, such as lakes or rivers. When used for water application, polymers should comply with Wisconsin Department of Natural Resource Technical Standard 1051, Interim Sediment Control Water Application of Polymers.

Selection

Polymers are available commercially in both granular and liquid forms in a wide variety of formulations.

Advantages

- Effective in preventing erosion
- Cost effective
- May reduce turbidity
- Reduces erosion during winter months, when vegetation cannot be established
- Prevents crust formations

Disadvantages

- Must be reapplied whenever the soil is disturbed and after large storm events
- May increase the pH of runoff
- Limited life span
- Does not provide protection for seed in the summer months
- Over application may result in negative effects on plants and wildlife
- Must be approved by WDNR and WDOT before use
- Cannot be used within 30 feet of state water bodies

However, both the Wisconsin Department of Natural Resources (WDNR) and the Wisconsin Department of Transportation (WDOT) must approve the polymer before it may be used. Polymers shall be utilized following all manufacturers' instructions and specifications. A current listing of approved polymers is available from the Product Acceptability List Committee on the WDOT's web site at: http://www.dot.wisconsin.gov/business/engrserv/pal.htm

APPLICATION

As application rates will vary depending upon the product used, the time of year, and the individual site characteristics, PAM shall be applied following the WDNR and the manufacturer's specifications. Over application may result in reduced effectiveness and may have adverse effects on local plant and wildlife communities. As a result, land applied PAM may not be applied within 30 feet of any state water bodies.

Reapplication is required after any site disturbance and after large storm events. In addition, because PAM breaks down over time, reapplication, based on manufactures specifications, is required for the practice to remain effective.

Additional practices, such as mulching, are strongly encouraged for use with polymers. The combination of these practices results in enhanced erosion protection, while increasing the success of germination by providing protection for seed.

DOCUMENTATION

Those utilizing PAM as an erosion control practice must maintain an inspection log that is readily attainable by Dane County Erosion Control Inspectors. Documentation requirements include:

- Date of application
- Rate of application
- Type of PAM applied (including manufacturer, product name and concentration)
- Specific area of the site that the practice has been applied
- Dates of inspection
- Date of construction activities on the application site
- Dates and amounts of rainfall on the site

MAINTENANCE

- Applied areas shall be inspected weekly and after each rainfall event for evidence of rill and gully formation
- PAM shall be reapplied necessary per manufactures' specifications
- PAM shall be reapplied after any site disturbance and after large rainfall events

METHOD TO DETERMINE PRACTICE EFFICIENCY

The efficiency of PAM is dependant upon the individual site characteristics, the type of polymer used, the rate of application, the time of year applied, and the use of additional practices. PAM efficiency is also dependant upon site disturbance. Any disturbance to the application area, such as vehicle traffic, grading, large storm events, etc., greatly reduces the efficiency of the practice and requires reapplication to prevent soil loss. However, when properly applied, PAM has the ability to reduce soil loss by 40%.

SOURCES

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3. Roa, A. *Screening of Polymers to Determine Their Potential Use on Construction Sites.* Publication No. 101-96, pp. 77-83. University of Idaho, Moscow, ID. 1996.
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5. Terrene Institute. *Cheap, Efficient Erosion Control Really Works.* Runoff Report. Volume 7, Number 3. May/June 1999.
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RAIN GARDENS

GENERAL

Rain gardens are shallow depressions that are designed to collect stormwater and promote infiltration, minimizing the amount of runoff from a site. These infiltration areas are planted with native vegetation, which act as a natural sieve, absorbs excess nutrients, and filters out pollutants (refer to Native Plants, pg. I.N-1).

Rain gardens should be located to intercept runoff along its natural path. When directing runoff naturally, grassed swales may be used as a conveyance structure (refer to Grassed Swale, pg. I.G-2). Rain gardens may be used on most any area of the site, excluding steep slopes, wetlands, floodplains, or in threatened or endangered species habitat. Rain gardens, while effective, generally are not designed for large storm events and, as a result, are best used in conjunction with other management practices.

ADVANTAGES

- Reduces the amount of runoff from a site
- Improves aesthetics and provides habitat for mosquito predators and other wildlife
- Appropriate for either new or retrofit applications
- Low maintenance

DISADVANTAGES

- Water quality impact from high traffic areas is unknown
- Longevity of the practice is dependant upon sediment accumulation and maintenance.

DESIGN

BASIN

Rain gardens should be designed to handle the 2-year, 24-hour storm and are most efficient with a storage volume that is equal to 10% of the impervious area of the site, with a maximum infiltration ponding depth of 12 inches. Side slopes of 6:1 or flatter are recommended to ensure the safety of the practice and to promote the establishment of vegetation.

VEGETATION

Rain gardens are planted or seeded with deeply rooted native vegetation systems because of their ability to absorb water, hardiness, natural beauty, and their ability to mitigate compaction. Plants must be selected to meet the needs of the site, wants of the individual users and, tolerate both wet and dry conditions. For all other selection criteria and specifics related to native species, please refer to the Native Plants section of this Appendix.

To improve the year-round aesthetics of this practice, select species that bloom at various times throughout the spring and summer.

SOILS

Rain gardens are very versatile structures and can be constructed on most any type of soil. Clay soils will generally pond runoff water for at least 72 hours, while well drained or sandy soils will infiltrate water more quickly. Fine textured soils will require shallower ponding depths and increased area.

CONSTRUCTION

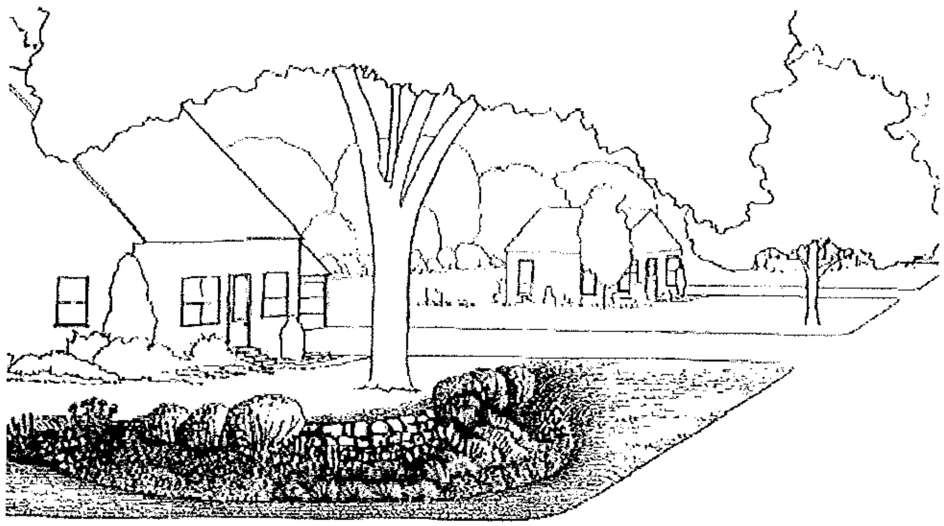
- Obtain all necessary permits and locate any underground utilities before construction begins
- Rain gardens should be located at least 10 feet from buildings
- To improve infiltration, compacted soils should be deep tilled to a depth of at least 12 inches (refer to Deep Tilling, pg. I.D-1)

Maintenance

- Rain gardens should be mulched until vegetation has become established, and once vegetation is established, it should be mulched as needed to help keep weeds down
- Plants should be watered at least weekly for the first 3 months, depending on the weather
- Vegetation should be weeded occasionally during the first year and at least twice a year (or as needed) after that
- All dead vegetation should be cut and removed once a year in the spring to allow for new vegetation growth

Method to Determine Practice Efficiency

Rain gardens are designed as an infiltration practice and do not significantly reduce the amount of suspended sediment in stormwater runoff. As a result, no efficiency is given for this practice. For purposes of Dane County Ordinances, rain gardens are not credited with sediment removal.



An Example of a Rain Garden

Source: Metropolitan Council. Adapted from Nassauer, et al., 1997.

Sources

1. Applied Ecological Services. *Confluence.* Vol. 6, No. 1. Pg. 5. Spring 2002.
2. Center for Watershed Protection. *On-Lot Treatment Fact Sheet.* Center for Watershed Protection, Inc., Ellicott City, MD. 1998.
3. "How to Build A Rain Garden." brochure published by Dane County Lakes and Watershed Commission, 2006 (available at: http://www.danewaters.com/pdf/HowToBuildaGarden.pdf).
4. International Science News. *Rain Gardens Help Replenish Dwindling Ground Water.* April 25th, 2002. http://unisci.com/stories/20022/0425026.htm.
5. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council. Minneapolis. 2000.
6. Nassauer, J., B. Halverson, B., and Roos, S. 1997. *Bringing Garden Amenities Into Your Neighborhood: Infrastructure for Ecological Quality.* Department of Landscape Architecture, University of Minnesota. Minneapolis.
7. Provisional Rain Garden Specification. City of Madison Engineering Division. December 2006. http://www.cityofmadison.com/engineering/stormwater/raingardenspec.htm.
8. Taylor Creek Restoration Nurseries. *Build Your Own Rain Garden.* Perennial garden Design Sheet #1.
9. University of Wisconsin-Extension. *Rain Gardens- A Household Way to Improve Water Quality in Your Community.* 2002.
10. Virginia Department of Forestry. *Rain Gardens.* April 25th, 2002. http://state.vipnet.org/dof/rfb/riparian/rain_gardens.htm.

SEDIMENT TRAP

GENERAL

A sediment trap is a small, temporary ponding area designed to catch and remove sediment from runoff. Runoff enters the trap and is impounded in a basin behind a stone weeper, reducing the velocity of the runoff and allowing suspended sediments to settle out.

Sediment traps are applicable on sites with drainage areas of less than 5 acres and are typically placed in swales and other conveyance channels (refer to Grassed Swale, pg. I.G-2). To maximize the effectiveness of this practice, they should be located on the lowest point, near the edge of the site, to maximize the area served by the trap. Because sediment traps are, at best, 70-80 percent efficient and are ineffective for smaller sized sediments, they are best used in conjunction with other BMPs.

ADVANTAGES

- Cost-effective
- Relatively easy to construct
- Low Maintenance

DISADVANTAGES

- Low trapping efficiency for fine particles
- Ineffective with large storm events
- Maximum life span of 18 months
- Maximum drainage area of 5 acres

DESIGN

Sediment traps must be designed for water quality control for storms up to the 1-year, 24-hour storm event. In addition, traps must also be capable of safely passing the 10-year, 24-hour storm event. Lengthening the basin, which increases the volume of the practice and detention time, may increase trapping efficiency. However, trapping efficiency is a function of particle size rather than of basin size, and, as a result, larger basins may or may not increase efficiency.

BASIN

The ponding area of a sediment trap shall have, at a minimum, a 2:1 length to width ratio. The banks of the basin shall be compacted during construction and must possess a maximum height of 5 feet, with a minimum top width of 4 feet and slopes 2:1 or flatter.

The basin should be seeded, mulched, and lined with a geotextile filter fabric, whose opening size will vary depending upon the soil type that is present on site.

OUTLETS

The crest of the outlet must be 1 foot below the top of the embankment, with weir length and stone size dependant upon the area drained by the practice. All other outlet criteria for this practice should follow the design specifications discussed in the stone weeper section of this appendix (refer to Stone Weeper, pg. I.S-12).

CONSTRUCTION

- Sediment traps should be operational before site grading begins
- Sediment traps should be removed after the site has been permanently stabilized

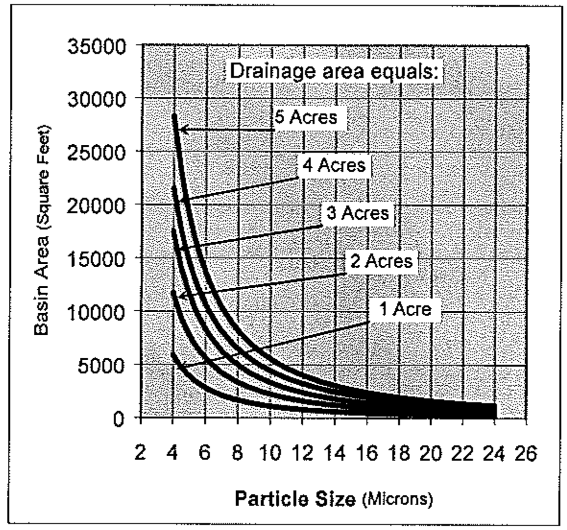
MAINTENANCE

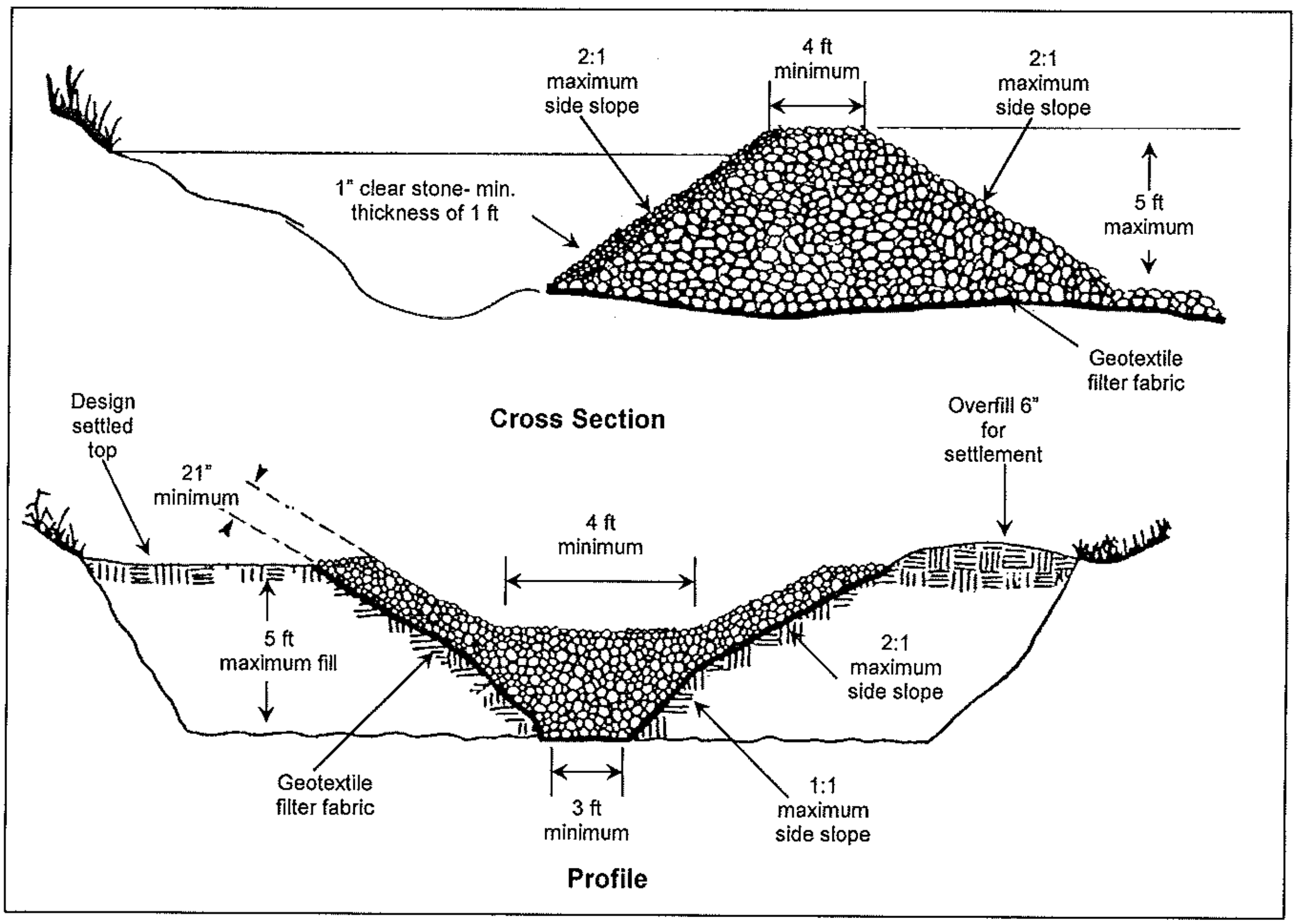
- Accumulated sediment shall be removed when it reaches ½ of the outlet
- Sediment traps shall be inspected for damage and repaired after each rainfall event
- If the sediment trap does not drain completely within 24 hours of a storm event, the geotextile and stone outlet should be cleaned

METHOD TO DETERMINE PRACTICE EFFICIENCY

Sediment traps reduce the flow velocity and allow sediment to settle out. The efficiency for this practice is dependent upon the proper design, installation, and maintenance of the structure. However, in general, sediment trap efficiency follows the ensuing graph.

Approximate Trapping Efficiency





Example of a Sediment Trap

Source: Adapted from North Carolina Erosion and Sediment Control Planning and Design Manual

Sources

1. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council. Minneapolis. 2000.
2. *National Catalog of Erosion and Sediment Control and Storm Water Management. Guidelines for Community Assistance.* United States Department of Agriculture, Natural Resources Conservation Service. Washington, D.C. 1996.
3. *Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater.* U.S. Department of Agriculture, Natural Resources Conservation Service and Mississippi Department of Environmental Quality. Washington, D.C. April 1994.
4. *Protecting Water Quality in Urban Areas, A Manual.* Minnesota Pollution Control Agency. St. Paul. 2000.
5. *Sediment Trap.* Conservation Practice Standard. Wisconsin Department of Natural Resources. November 2006.

SEEDING

(TEMP)

GENERAL

Temporary seeding stabilizes disturbed areas with fast growing annual grasses, small grains, or legumes until permanent vegetation can be established. Dense, established vegetation protects the soil from raindrop impact, reduces flow velocities, increases infiltration, reduces soil loss from the site and is the most effective erosion control practice available. In addition, temporary seeding is economical and adds organic matter to the soil and reduces dust and mud problems that are common on many construction sites.

Temporary seeding is applicable on any area of the site that will remain inactive for at least 21 days but less than 1 year. It is often used to prevent erosion between construction activities and during the winter months if established early enough. Due to its short-term nature, temporary seeding may be ineffective on its own and should be used in conjunction with other management practices.

ADVANTAGES

- Cost-effective
- Easy to apply
- Requires little maintenance
- Increases infiltration and water retention
- Adds organic matter for permanent seeding
- Reduces dust

DISADVANTAGES

- Use limited by the growing season
- Maximum life span of 1 year
- Requires the addition of fertilizer on infertile soils

DESIGN

VEGETATION

Temporary vegetation provides effective erosion control only once densely established. "Dense" is defined as a stand of 6-8 inch vegetation that uniformly covers at least 70% of a representative 1 square meter plot. Until vegetation is permanently established on site (generally 60 days after it has been planted) it should not be relied upon to prevent soil loss.

Type of Cover	Minimum Seeding Rate
Spring Oats	3 bushels per acre
Sudangrass	35 lbs. per acre
Cereal Rye*	2 bushels per acre
Winter Wheat*	2 bushels per acre
Annual Ryegrass	25 lbs. per acre

* Rye and winter wheat will be destroyed by seedbed preparation at the next permanent seeding period

Source: Natural Resources Conservation Service

The species of vegetation selected will vary depending upon the soil type, slope, and the time of year it is applied. Common types of temporary vegetation include Wheat, Rye, Spring Oats, Annual Ryegrass and Sudangrass. These annual species establish themselves quickly under the proper growing conditions and require minimal maintenance. Care should be taken when selecting a species to avoid the use of exotic or invasive species, as they may upset the balance of the local ecosystem.

The seeding rates, depths, and times of application supplied here are intended only as general guidelines. All manufacturers' guidelines should be carefully followed to ensure the success of this practice.

SEEDBED PREPARATION

To be successful, permanent seeding requires a properly prepared seedbed. Areas that are limited by poorly drained soils, steep slopes, or that allow concentrated flow to develop should not be used for seedbeds unless amendments are made.

Soils should be tested for nutrient content and pH to determine the amount, if any, of fertilizer or lime required. Over-application of these soil amendments is costly, ineffective, and may cause serious pollution problems. As a result, lime and slow releasing fertilizers should be applied only as needed and should be incorporated into the soil to keep them on site and in the root zone.

The organic content of the soil is also an important consideration when preparing the seedbed. Soils rich in organic matter possess high levels of nutrients and microorganisms, which improve the growth rate, require less fertilizer to be applied, and increase the porosity of the soil. To improve the organic content of the soil, organic compost may be incorporated into the top ten inches of soil.

A minimum of 3-4 inches of topsoil is required for permanent vegetation. It should be loose, uniform, and well pulverized to promote rapid growth. Compacted soils should be loosened to a depth of at least 6-8 inches by using a chisel plow or similar implement to ensure adequate pore space.

Application

Seed should be applied uniformly following the supplier's recommendations by broadcast seeding, hydroseeding, or drill seeding. Broadcast seeding involves scattering the seeds on the soil surface by hand or mechanical means and is best utilized on smaller areas and for patching applications. After application, the site should be raked and firmed with a roller or cultipacker. Seeded areas should then be mulched to provide protection for the seed and to reduce erosion before the vegetation becomes established (refer to Mulching, pg. M-2.1).

Hydroseeding and drill seeding are more costly than broadcast seeding and are used on larger sites to maximize the application's cost effectiveness. Hydroseeding, a method that mixes the seed and water together into a slurry, is applied on areas that may be difficult to seed with alternative means. Other amendments, such as tackifiers, polymers, fertilizers, and/or fiber mulch are often added to the slurry, which is sprayed on, to protect the seed and to promote its growth. Drill seeding utilizes a drill or cultipacker seeder to inject the seeds beneath the soil surface. Seed depth is set based upon the supplier's specifications, but generally is ¼ - ½ inch deep for grasses and legumes. Drilling, while more costly than broadcast or hydroseeding, is generally very effective when performed properly because the seed is protected from wind, water, and wildlife.

Construction

- All tracking and grading should be completed before temporary seeding begins
- All management practices should be installed and online before seeding
- Seedbed should be adequately prepared before seeding begins
- To promote growth, seeding should not be performed during excessively wet conditions, as soils may become excessively compacted

Maintenance

- Inspect seeded areas weekly after planting to ensure that vegetation is adequately established, reseed as necessary
- Seeded areas should be inspected after each rainfall event to check for evidence of erosion and bare spots
- Add fertilizer as necessary at proper rates
- Water seeded areas regularly until they become established

Method to Determine Practice Efficiency

The efficiency of this practice is derived from reducing the amount of time that the site is left bare and exposed. To determine the efficiency for this practice, use the new, shortened exposure time and replace the pre-existing one in the USLE and recalculate. The difference between the two equations is the efficiency for the practice.

Sources

1. *Indiana Handbook for Erosion Control in Developing Areas.* Indiana Department of Natural Resources, Division of Soil Conservation. Indianapolis. 1994.
2. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council. Minneapolis. 2000.
3. *National Catalog of Erosion and Sediment Control and Stormwater Management. Guidelines for Community Assistance.* U.S. Department of Agriculture, Natural Resources Conservation Service. Washington D.C. 1996.
4. *Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater.* U.S. Department of Agriculture, Natural Resources Conservation Service and Mississippi Department of Environmental Quality. Washington, D.C. April 1994.
5. *Protecting Water Quality in Urban Areas, A Manual.* Minnesota Pollution Control Agency. St. Paul. 2000.
6. *Seeding For Construction Site Erosion Control.* Conservation Practice Standard. Wisconsin Department of Natural Resources. November 2006.
7. *Water Related Best Management Practices in the Landscape.* U.S. Department of Agriculture, Natural Resources Conservation Service and Center for Sustainable Design at Mississippi State University. Washington, D.C. 1999.
8. *Wisconsin Construction Site Best Management Practice Handbook.* Wisconsin Department of Natural Resources. Madison. 1989.
9. *Wisconsin Field Office Technical Guide.* U.S. Department of Agriculture, Natural Resources Conservation Service. Washington D.C. 1993.

SILT FENCE

GENERAL

A silt fence is a temporary structure, constructed of woven geotextile fabric attached to posts, which minimizes the loss of sediment from a site and prevents sheet and rill erosion. These structures intercept runoff and force it to pass through the fabric, reducing its velocity and allowing suspended sediments to settle out upslope of the silt fence.

Silt fences are typically used on construction sites to trap sediment on site and around soil piles and may not be used in channels, gullies, ditches, streams, or in any other area where concentrated flow may occur. These structures, which may be prefabricated or constructed on site, should be installed prior to site disturbance. Because silt fences have a high rate of failure without proper installation and maintenance, they are best used in conjunction with other BMPs.

Silt fences must be removed and disposed of after the site has been stabilized and permanent BMPs have been established.

ADVANTAGES

- Low cost
- Versatile

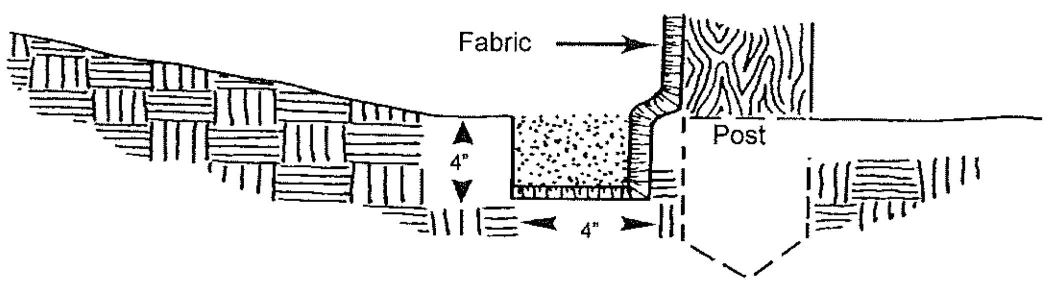
DISADVANTAGES

- Ineffective for concentrated flows
- Requires frequent maintenance
- Maximum life span of 1 year
- Drainage area should not exceed 0.25 acres per 100 feet of fence length
- High rates of failure if not installed properly
- Ineffective on slopes greater than 50%
- Labor-intensive to install

DESIGN

Silt fences must be designed to handle the runoff from the 10-year, 24-hour storm event, with a maximum drainage area of 0.25 acres per 100 feet of fence.

Silt fence height will vary upon the site and application of the practice, but must be between 14 and 28 inches, measured from the top of the fabric to the soil surface, and does not include any portion of the fence below ground. Silt fences should be installed in a crescent shape, parallel to the contour of the land, with the ends placed upslope of the center. This practice prevents water from escaping around the ends of the fence and forces it to pond behind it. Ponding depth must not exceed 2 feet, as greater depths greatly increase the likelihood of failure. Stabilized outlets should be placed at the ends of the fence to provide an overflow and protect the fence during larger storm events.



Proper Entrenching of a Silt Fence

Source: Wisconsin Department of Commerce

Silt fences are not recommended for use on slopes that exceed a 2:1 ratio. However, they may be used in series for flatter slopes if the spacing guidelines below are followed. Additional structures, however, do not increase the permissible slope length.

Silt Fence Spacing Guidelines	
% Slope	Maximum Slope Length Draining to Fence
< 2%	100 feet
2 – 5%	75 feet
5 – 10%	50 feet
10 – 20%	25 feet
> 20%	15 feet

Source: Adapted from WDNR

Materials

Fabric

A woven geotextile fabric should be used and must meet the following criteria:

- Minimum grab strength of 100 pounds
- Pore size of between 50 and 140 microns
- Ultra-violet radiation stability of 90% (Using test method ASTM D-4355)
- The use of a top support device, such as a heavy-duty nylon cord or equivalent

The fabric should be anchored by burying at least 8 inches in a 4x4-inch trench, with the bottom 4 inches of fabric extending upslope. Joints in the fabric should be minimized to prevent failure of the fence. Where joints are necessary, each end of the fabric should be securely fastened to a post. The posts should then be wrapped around each other to produce a stable, secure joint or may be overlapped to the next post.

Support

Silt fences may be supported by either steel or hardwood posts. The strength, dimensions, and depth of the posts will vary upon the load that they are designed to support. As a result, only the minimum dimensions are listed here. Steel posts must be at least 5 feet long with a strength of 1.33 lbs/ft. (2 kg/m) and have projections for the attachment of fasteners. Hardwood posts must be air or kiln dried and measure at least 1 1/8 inches square, with a minimum length of 3 feet for a 24-inch fence. All posts should be driven at least 20 inches below ground and should be spaced a maximum of 8 feet apart to provide proper support.

The geotextile fabric should be attached in at least 3 places to the posts on the upslope side with either ½ inch staples, 50 lb. plastic zip fasteners, or wire fasteners. To prevent damage to the fabric from fasteners, the protruding ends should be pointed away from the fabric.

For added strength and stability, silt fences may be reinforced with wire mesh. When used, the mesh should be installed behind (downslope) the geotextile fabric and in front (upslope) of the posts. The wire mesh should be attached to the fabric in at least 3 places, using wire fasteners spaced at a minimum distance of 2 feet.

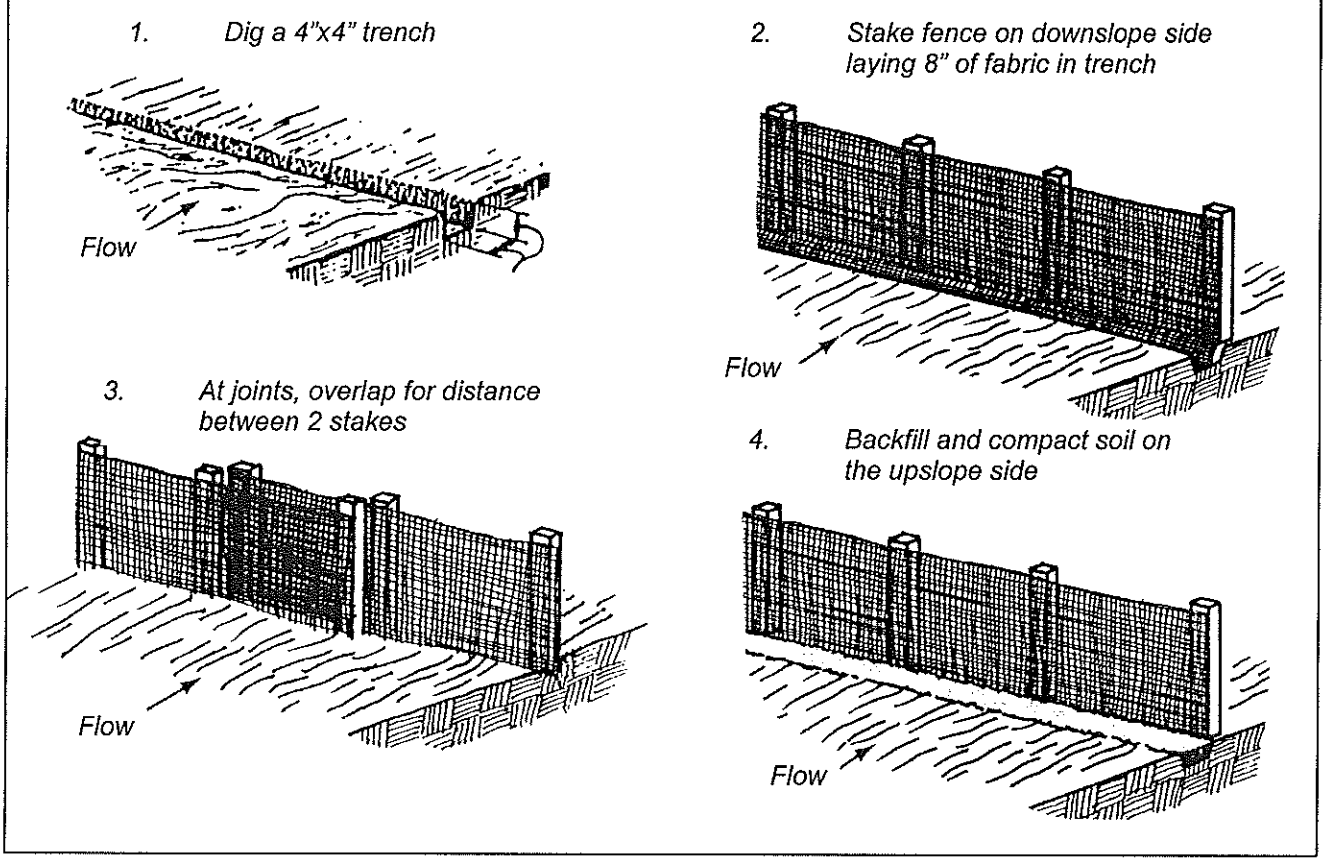
Maintenance

- Silt fences should be inspected weekly and after each rainfall for damage – all repairs should be made immediately
- Accumulated sediment should be removed once it reaches ½ the height of the fence to ensure that a proper storage volume is preserved behind the fence
- Silt fences should be replaced when worn out

Method to Determine Practice Efficiency

A silt fence prevents soil loss by reducing the flow velocity of runoff by forcing it through fabric. When properly installed and maintained, a silt fence with a 20-micron pore size yields an efficiency of 42%.

PROPER SILT FENCE INSTALLATION



Source: North Carolina Erosion and Sediment Control Planning and Design Manual

SOURCES

1. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council. Minneapolis. 2000.
2. *North Carolina Erosion and Sediment Control Planning and Design Manual.* North Carolina Sediment Control Commission, Department of Natural Resources and Community Development. 1988.
3. *Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater.* U.S. Department of Agriculture, Natural Resources Conservation Service and Mississippi Department of Environmental Quality. Washington, D.C. April 1994.
4. *Silt Fence.* Conservation Practice Standard. Wisconsin Department of Natural Resources. November 2006.

PERMANENT DIVERSION

General

A permanent diversion is a vegetated channel that is designed to intercept and collect runoff, diverting it down slope to an area that is less susceptible to erosion. Diversions are constructed upslope of areas where erosion is likely to occur and, by reducing runoff velocities, allow sediments and soluble pollutants to settle out.

Permanent diversions can be used in residential, commercial, and industrial areas and include: graded surfaces to redirect sheet flow, dikes, berms, and conveyance structures such as swales, channels, gutters, and drains.

Advantages

- Can significantly reduce erosion from a site
- Removes sediment and soluble pollutants
- Can be aesthetically pleasing if designed properly, which can increase adjacent property values

Disadvantages

- Requires a relatively large land area
- Are not recommended down slope of high-sediment producing areas
- Ineffective on sites with slopes greater than 15%

Design

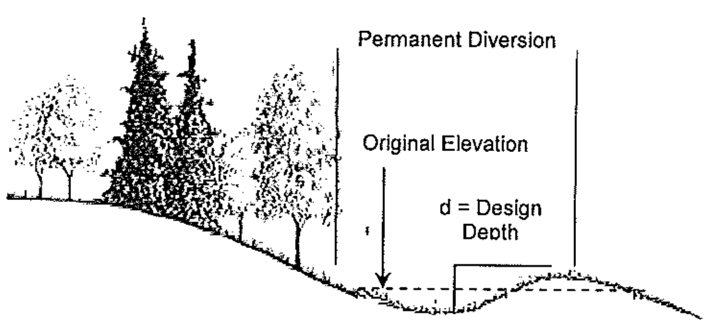
Capacity

Permanent diversions should be designed, at a minimum, to convey the runoff from a 10 year, 24-hour storm event with at least 0.3 foot of additional capacity (freeboard). However, it is recommended that diversions that protect roads and urban areas have a capacity sufficient to transport runoff from the 25 year, 24-hour storm event. In addition, the designed capacity must take into account any soil settling that may occur. While the amount of settling that occurs will depend upon the type of soils present on site, a minimum value of 10% should be used.

Shape and Slope

Permanent diversions may be parabolic, trapezoidal, or V-shaped with a minimum ridge width of 4 feet.

Side slopes should be flatter than 3:1, as steeper slopes may be unstable and make maintenance activities more difficult. Channel slopes will depend upon the topography of the site, but should be designed so that sheet flow is sustained and water velocities are maintained below 5.0 ft/s.



An Example of a Permanent Diversion
Source: Adapted from United States Natural Resources Conservation Service

Permissible Velocities for Diversions (ft/s)

Soil Texture	Bare Channel	Channel Vegetation		
		Poor	Fair	Good
Sand, silt, sandy loam, and silty loam	1.5	1.5	2.0	3.0
Silty clay loam and sandy clay loam	2.0	2.0	3.0	4.0
Clay	2.5	2.5	4.0	5.0

Source: Adapted from Wisconsin Field Office Technical Guide

Outlets

The outlet selected for each diversion will vary upon the needs of each site. Outlets should be stable and non-erosive and may be vegetated, paved, rock-lined with geotextile fabric, or drain tiled. If a vegetated outlet is chosen, it must be constructed before the rest of the diversion to allow time for the vegetation to become established. Outlets may also incorporate riprap or gabions to further prevent erosion and reduce the velocity of outflows.

Vegetation

Plant species selected for permanent diversions should meet the following criteria:

- Native species may be used with careful selection (refer to Native Plants, pg. I.N-1)
- Species should be tolerant to frequent inundation as well as extended dry periods
- Species should be resistant to matting
- Species should form a dense cover
- Avoid exotic, noxious, and invasive species

Construction and Maintenance

- Vegetation should be established immediately after grading is complete to prevent erosion of the structure
- Until vegetation is established, diversions should be inspected after each rainfall for signs of erosion
- After establishment, permanent diversions should be inspected annually to ensure that they are operating properly and to check for any potential problems
- Mowing should be performed only during dry periods using light equipment to prevent soil compaction

Method to Determine Practice Efficiency

Diversions effectively reduce the slope length by diverting runoff away from slopes and other areas that are prone to erosion. The efficiency for this practice is thus derived from the reduction in slope length that it provides. To calculate the efficiency, simply use the new, reduced slope length in place of the pre-existing one in the USLE and recalculate. The difference is the efficiency for the practice.

Sources

1. *Construction Site Diversion.* Conservation Practice Standard. Wisconsin Department of Natural Resources. November 2006.
2. *Minnesota Urban Small Sites BMP Manual.* Metropolitan Council. Minneapolis. 2000.
3. *Wisconsin Field Office Technical Guide.* U.S. Department of Agriculture, Natural Resources Conservation Service. Washington D.C. 1993.